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THE ACCURACY OF LABOR

SUMMARY

I. All products inaccurate; need of tolerance, 687. — Tactile pressure, and its delicacy in arts and crafts, 688. — II. Physiological causes of differences between individuals in accuracy of work, 690. — Memory and attention, 691. — No measure of accuracy or of labor, 693. — III. Differences in wages based on differing accuracy, 695. — Division of labor on that basis, 696.

I

Even when describing the more complex phenomena of labor, like wages, economists tacitly assume that any piece of finished work has been finished just as intended, fully and exactly. This is not the case; and moreover it has not even once been done in the history of mankind and never will and never can be done. Nothing in the world seems simpler than to duplicate the length of a yard stick. There are not two yard sticks in the world that have exactly the same length. The coinage of twenty-dollar gold pieces is attended to with great care, and is done with the most delicate machinery. Nevertheless, no twenty-dollar gold piece has ever been turned out that contains exactly the amount of gold it should contain according to the intention of the makers, or has the intended size or thickness. A rifle is not a very complicated machine. To have some parts of it made in one factory, other parts in another and still others in a third, according to clear and simple measurements, seems easy. Nevertheless this very scheme was found impossible of execution during the war because it was found that the parts when assembled did not fit; and according to the experts, could not be manufactured to fit. Nothing seems simpler than to punch holes in two plates to be riveted together so that the holes should coincide. But it is a practical impossibility, as has been found in boiler making. The coincidence is "forced" and this frequently induces stresses in the plates giving rise to boiler explosions. The screw is one of our most important tools. For many practical and scientific purposes it would be most desirable to have a perfect screw, but none has ever been made. Even coarse tests applied to ordinary screws show them to be inaccurate in pitch and to have wavy or "drunk" threads and uneven diameters.

Knowing the utter inability of man to produce any article with absolute accuracy, certain limits, often called tolerance, have been established within which the inaccuracies must be kept. In the case of the fineness of gold coins the customary tolerance (or "allowance") is two parts in one thousand. That even with this considerable tolerance the task of coining is not an easy one appears from the fact that frequently more than 10 per cent of the coins do not come within the tolerance and have to be rejected and remelted. In silver coins the customary tolerance for fineness is about twice as great as for gold. Therefore the proportion of coins that have to be remelted is smaller, often less than 1 per cent.

Similar tolerances are established for weights and measures. In fact, in every kind of labor there is a customary tolerance. It is clear that it is much greater in cutting granite blocks for pavements than in cutting diamonds for ornaments. The labor of making them is practically of the same kind, exerting a tactile pressure on a tool, and through it on the object. In many kinds of labor this tactile pressure is the main labor. Now the production of tone on a violin is brought about by practically the same kind of labor as is employed in cutting granite or diamonds, or in carpenter work, namely, by exerting pressure on a tool, in this case the bow. The phenomenon of tone production on a violin is better known than the phenomena of pressure in the handicrafts because it can be investigated by one of our sharpest senses, the ear. Therefore, it may well serve to illustrate the difficulties of remaining within the tolerance of any task performed by tactile pressure.

The bow is a lever the fulcrum of which is formed by the thumb and the middle finger. The pressure is exerted by the index finger. The bow is a one-armed lever, the pressure is exerted at a point about one inch from the fulcrum while the resistance is met wherever the string touches the bow. At the end of the bow, which is about twenty-five inches long, a resistance of one twenty-fifth of the finger pressure will balance the pressure, according to the laws of physics. Here the first difficulty of exerting pressure accurately is evident. When it is intended to produce a long note of even strength, the bow is drawn across the string downward or upward for its full length. Therefore in the downstroke the leverage of the resistance is constantly increasing and in order to maintain the same pressure on the string, the pressure of the index finger on the bow must be constantly increased. To increase or decrease such pressure at the same rate as the bow moves down or up (disregarding here the weight of the bow) is extremely difficult. To produce a good tone of absolutely even strength, or rather one within the tolerance of the ear, is a feat that few violinists can accomplish. If a composition is to be played properly, the minute changes in the pressure of the index finger become bewildering in number and degree.

The same difficult task of exerting a certain pressure on a tool presents itself to every craftsman. Especially in the last fifty years the requirements of labor have become almost as stringent as those of the violin artist. Many new tools, the gauges, have been constructed to enable the workman to check the accuracy of his work. In many cases it is found that hand labor is superior to machine work. Contrary to what one would expect, the former is capable of greater accuracy than the latter. This is shown in trifling things, as in the finery of women as well as in massive objects, such as certain parts of the manufacture of steel. Watches are made by machine, but finished by hand; the modern watchmaker is an engineer, with an engineer's requirements for accuracy. Bookbinding is largely done by machine, but high-class work must be done by highly skilled hand labor.

Small as the differences of accuracy are, their economic influence is enormous because they may totally nullify the result. Coins may have to be remelted if they do not come up to the desired accuracy and the labor of the first operation is entirely lost. In the manufacture of iron a difference in the coal, sulphur, or phosphorus contents as small as one part in ten thousand makes a noticeable difference in the brittleness of the iron or steel. A difference in the aluminum contents as small as one part in fifty thousand may make the product unsuited for the purpose in view, so that the whole has to be remelted. In making telescopic lenses, the tolerance is so extremely small that it constantly endangers the result.

II

It is a matter of experience that not every violinist is a Kreisler, that not all workmen can perform accurate work to the same degree. The question then arises, why is there such a difference in men doing the same work, namely, pressing a tool against an object, the string, the granite, or the diamond ? The answer to this question is found in certain physiological and psychological qualities, which are found to be different in different men.

Among the many physiological differences in men four are of main interest here. The first is connected with Fechner's psychophysical law, according to which the stimulus may increase without increasing the sensation. An added stimulus increases the sensation only if it is greater than a certain minimum, and this minimum for sensations of medium intensity is found to be a *fixed* proportion of the stimulus already acting. For instance, in the case of tactile pressure, which as shown above is the chief means of accuracy in crafts, "we can just tell a weight of twenty grams (three hundred and ten grains) from one of thirty (four hundred and sixty-five grains); or of forty grams (six hundred and twenty grains) from one of sixty (nine hundred and thirty grains)." [1] An individual whose fixed proportion is less than the average of one-third obviously distinguishes tactile pressures more accurately than an individual whose fixed proportion is one-third or higher, and similarly with all other senses and sensations.

A muscle does not respond to every stimulus, however small. There is a minimum stimulus, called the stimulus of threshold values, below which the muscle does not act. Furthermore, a small but appreciable period of time, called the latent period, elapses in which the muscle gets ready, as it were. When it begins to act it does not instantly contract in accordance with the size of stimulus, but contracts first slowly and to a small extent, then very rapidly in accordance with the stimulus. These three phenomena: the threshold value, the latent period and the slow, small start of the muscle, are of great importance to accuracy. No man can exert a pressure exactly as he wills it. As soon as the muscle begins to contract, when its contraction is still very small and slow, a worker can judge from his sensation and his memory whether the contraction of the muscle is precisely that he had willed or not, just as the mathematician can tell from three points of a circle the diameter, or a zoölogist from a single bone, the animal. If it is not, he immediately corrects it by another pressure. The shorter the latent period is, the quicker this correction can be applied and the smaller the inaccuracies. Violinists are familiar with the phenomena of these constant corrections. The same holds good in cutting diamonds and in every other labor requiring accuracy. That people differ in size of the threshold value, in the length of the latent period, and in the muscle action curve, is clear; and this is a potent cause for differences in accuracy.

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[1] The Human Body. By E. Z. Martin, p. 179.

The mental capacities influencing the accuracy of labor, in which men differ largely, are memory and attention. The memory of muscular sensation, especially of small differences in them and their coördination, is very limited and quite fugitive, so that it must be constantly refreshed. This phenomenon is found in every craft, even in every game. The apparently simple processes of knitting or wielding a golf stick require the action of many muscles and their coördination. They are difficult to remember. Constant practice, constant repetition is necessary to enable one to execute the proper tactile pressures, that is to say, to set in motion the right muscles at the right time with the proper tactile pressure and in the right sequence.

Attention is another mental capacity required for accurate work. It has been defined as the concentration of one's consciousness on an object or on several objects.

I believe a distinction should be made between attention that is directed toward one or several objects and attention that is directed toward the *relation* between several objects. The degree of attention in the first case I propose to call the depth of attention and the degree of attention in the second case the width of attention. For accurate work both depth and width are necessary. Depth of attention is not rare among men. It is found even in children. An individual when in attention seems to contract slightly all muscles. The threshold stimulus, the latent period, as well as the period of small muscle reaction, seem to be much smaller under attention than they are ordinarily, and thus the accuracy is increased.

Width of attention is rare. Extraordinary width of attention is possessed only by a genius.

The difference in the two kinds of attention shows itself clearly in business. It is comparatively easy to secure a manager for the departments of buying raw material, of manufacturing it, and of selling it. But very rarely can a man be found who can keep the three departments properly balanced so as to maintain without interruption a steady stream from the raw material to the sales of the finished product. In the arts, the same distinction holds good. Kubelik is a wonderful performer on the violin, but he is inferior to Kreisler. Both play each note, each phrase, each theme, with consummate art, because both possess in addition to their unusual physiological equipment unusual depth of attention. But Kreisler does, and Kubelik does not, possess the width of attention which coördinates the repetition of the themes and subordinates them to the climax so as to make an entity of the composition. It is true in science. Ptolemy described the course of each planet — he had depth of attention. Kepler found several relations between them — he had width of attention.

There exists no commonly accepted measure for accuracy. In cases where it can be expressed in tolerance, the latter is a good physical measure. If a specified accuracy is required in certain work, then any work below that tolerance becomes economically null and void. Any work above it is sometimes not distinguished economically from the required tolerance. Frequently, however, differences within the tolerance, called quality, are recognized economically. If the accuracy required in two pieces of work and done by two different men is the same, they can indeed be compared by the number of foot pounds and time measure. Under that assumption, and only under that, it can be said that the products of labor "represent definite masses of crystallized labor time. They are nothing more than materialization of so many hours or so many days of social labor," [1] — and that "all labor of a higher or more complicated character than average labor is labor where production has cost more time and labor than unskilled or simple labor power." [2] If the term "complicated character" means higher accuracy, this fundamental Marxian doctrine is not tenable. Labor of a certain accuracy cannot be reduced to terms of labor having less accuracy but more time or more quantity. The two are simply incommensurate, because the laborer of less accuracy cannot perform a day's work of the more accurate man, even if he work a lifetime. A cutter of granite blocks can never cut a diamond properly. To measure and compare two pieces of work of different accuracies by labor time is just as impossible as to measure and compare the cubic contents of two boxes by square feet.

The phenomena of accuracy and tolerance are found even in inorganic nature. Natural forces seem to be unable to achieve the results with that accuracy which our theoretical consideration would lead us to expect. There never has existed in nature a single specimen of chemically pure chemical or mineral, nor has man ever been able to manufacture one. If the tolerance is within certain limits we call the specimen chemically pure, but we know it is not chemically, exactly pure. The copper of Michigan differs in electric properties from copper of every other region, altho they are "chemically pure." Diamonds are "chemically pure carbon," but some are blue, some white, some yellow. Two pieces of the purest coal of two different localities differ in their coke-making properties. Granite of Vermont differs from that of North Carolina in its resistance to the elements. Innumerable other examples could be given; it suffices to point out that the phenomena of accuracy exist even in organic nature and are "born" and not acquired.

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[1] Marx, Capital, chap. vii, sec. 2.

[2] Ibid., end of chap. vii.

The phenomena of accuracy and tolerance are seen in bewildering richness in the organic world. Nature has not been able to make even two peas exactly alike. Here we can determine the tolerance very sharply. The line is drawn by viability. An accuracy that will permit viability is within the tolerance; otherwise it is outside. The accuracy of nature in fertilizing pollen of plants or eggs of animals is surprisingly small. In general, nature exhibits very poor workmanship; she is an unskilled worker. If, said Helmholtz, a maker of optical instruments were to tender him an instrument so imperfect, so poorly done, as the human eye, he would indignantly refuse to accept it.

One more example of the enormous importance of tolerance may be given. The organs of the human body fulfill its functions with a certain tolerance. We may eat and drink somewhat more or less of every food, of every potion. An individual with a large tolerance has abundant health; one with a small tolerance is an easy prey to disease. The chief purpose of diet is to restrict oneself to the foods for which one's organs have a comparatively large tolerance.

III

Two products of labor that require the same quantity and time of labor, or rather, the same amount of "crystallized labor time," will give the workers the same wage, if the accuracy required, that is to say the tolerance permitted, is the same in both cases. If, however, the tolerance required is smaller in the one case than in the other, the wage of the first worker will be higher and will be determined by the law of supply and demand. After a commercial tolerance has been established there exists competition among those capable of working within that tolerance. If there is only one individual possessing a required tolerance, as for instance in the case of Kreisler, then the wage is determined by the laws governing monopolies.

The following examples from the tool mills at Cleveland illustrate the connection between tolerance and wages (before the war). There are three great groups of workers: tool makers, machine men in the tool room, machine men in the shops. The tool makers receive 75 cents to 85 cents an hour; the tolerance permitted in their work is $\frac{1}{10,000}$ of an inch. The machine men in the tool room receive 40 cents to 55 cents an hour; the tolerance in their work ranges from $\frac{1}{1000}$ to $\frac{1}{2500}$ of an inch. The machine men in the shop receive 35 cents to 40 cents; the tolerance permitted in their work is $\frac{1}{100}$ of an inch. The wages of the subdivisions in the three groups are also determined by the tolerance permitted.

Another instructive example is found in the common practice of making statues. After the figure is mapped out roughly by holes in the block, a practically unskilled man is entrusted with removing most of the superfluous stone. Then the block is turned over to a *skilled* chisel-man, the scarpellino. He stops his work outside the excess tolerance. The final labor, of reducing the statue to or within the tolerance is done by the artist himself.

As there are different "dimensions" of labor, and as they can be combined in different ways, there are different kinds of the division of labor, as to: (*a*) quantity, (*b*) time, (*c*) accuracy, (*d*) both as to quantity and to time, (*e*) quantity and accuracy, (*f*) time and accuracy, (*g*) quantity, time and accuracy.

Each division of labor has certain advantages, and also certain disadvantages, inevitably connected with it. Only the last kind will be discussed here.

The most important division of labor is that based on accuracy. People are born with different capacities as to accuracy, with different capacities for instance, to exert and to distinguish tactile pressure. The ideal division has taken place when every man labors at work needing his accuracy to the very limit of his capacity. It is plain that this division can emerge only at a very high stage of civilization, because the very highest accuracy has nothing to work on at the lower stages. There was no need for gauges in Caesar's time, and among the shepherds of Palestine the finest grade of steel would not have been appreciated more than iron.

As shown above, accuracy is inborn, not acquired. There are no statistics that show us how many people possess a certain degree of accuracy. In fact the possessor of that gift is usually ignorant of it himself. It must be coaxed into publicity. The higher price paid for its product is the means by which this is done. The surplus over and above the price of the product of unskilled labor is so determined as to establish a steady supply or discovery of workmen possessing the required accuracy.

The skilled worker is the recipient of an unearned increment, or rather of an increment that is not due to his quantity and time measure of labor. This unearned increment is the divining rod that discovers just in what direction an individual's capacities have the greatest accuracy.

The division of labor for accuracy has so many tremendous advantages and so few disadvantages that it stands forth easily as the foremost economic achievement of man. It brings to light the individual's memory, and his depth as well as width of attention. It is the mother of all literature, arts, and sciences. It has transformed the slave of supernatural fears into the master of natural forces. It makes the desert bloom and the stars give up their secrets.

L. KOTANY.